The Research of Heating Temperature for Shrinkage Fit Corona Ring of SF_6 Switchgear

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Abstract: SF_6 gas insulated metal enclosed switchgear widely applies shrinkage fit Corona Ring, match dimension of this type of Corona Ring and conductor is interference fit, by utilizing thermal expansion property of the material, expand match dimension of the Corona Ring via heating so that the dimension of Corona Ring and conductor coordinates into clearance fit. After the assembly, Corona Ring is cooled off and shrink to the dimension before expansion, connection between conductor and Corona Ring is tighter. Proper heating temperature is the guarantee of assembly clearance. Currently applied heating temperature causes undersize assembly clearance, which leads to the problem of incomplete installation of Corona Ring, causing high rate of rework and scrapping. This article defines appropriate heating temperature by researching and testing heating temperature of aluminum Corona Ring for shrinkage fit of SF_6 switchgear, solves the problem during manufacture and installation.

Key words: Corona Ring, heating temperature, expansion, dimension fit

Preface

Conductive connection part of SF_6 gas insulated metal enclosed switchgear applies Corona Ring to improve electric field distribution, two assembly modes of Corona Ring are applied, one is bolt-on connection, the other is shrinkage fit, main material for shrinkage fit is antirust aluminum 5A02, mean coefficient of linear thermal expansion of 5A02 is $25.4\times10^{-6}K^{-1}$(20~300℃)[1] [2], installation of Corona Ring utilizes thermal expansion property of aluminum alloy material and enables interference fit at ambient temperature to shift shape into clearance fit after thermal expansion. This assembly mode has an evident advantage in contrast to bolt-in mode, no metal dust will be produced during assembly process which greatly contributes to eliminating product internal metal particles. For assembly of shrinkage fit Corona Ring, improper heating temperature causes expansion of Corona Ring fitting dimension and doesn't meet requirement of clearance fit for assembly, greatly lowers rate of assembly success.

This article conducted research and analysis on relation of shrinkage fit Corona Ring fit dimension and temperature via test data, acquired empirical algorithm applying approximate arithmetic, then apply computed proper heating temperature on basis of fit dimension tolerance, provides reference for fit dimension design of Corona Ring with similar structure.

1. Research and schematic design

Working principle of GIS shrinkage fit Corona Ring utilizes thermal expansion property of aluminum alloy material, as shown on figure 1, dimension of Corona Ring (φ 109) and fit dimension of conductor (φ 109) is interference fit, dimension φ 109 will be enlarged when Corona Ring is heated so that it coordinates with conductor fit dimension and shift in clearance appropriate for assembly.

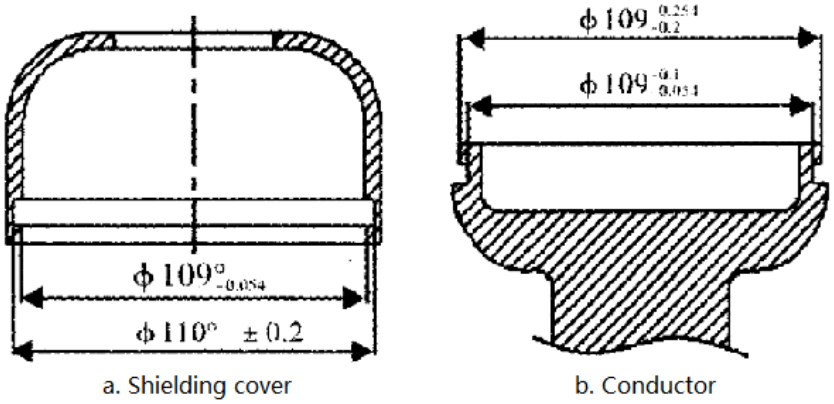

Figure 1

A proper heating temperature must be defined to acquire appropriate fit clearance for assembly. In accordance with illustrations on work instruction, fit clearance of assembling dimension is inadequate when heating temperature of Corona Ring reaches 180℃, rejection rate during the assembly process is high which substantially affects quality and progress of Corona Ring assembly.

In order to improve assembly qualified rate of shrinkage fit Corona Ring, a proper heating temperature is necessarily required. Simply raise heating temperature of Corona Ring not only prolongs heating time, adds electricity consumption, but overheat may also lead to high temperature annealing of antirust aluminum 5A02[3] [4], thus weaken material strength. For purpose of defining proper heating temperature, approximate arithmetic is applied to fit relativity algorithm between Corona Ring fit dimension expansion rate and temperature with fit dimension after thermal expansion of GIS shrinkage fit Corona Ring.

2. Test, analysis and verification

Select 10 Corona Ring, test fit dimension after thermal expansion. In consideration of high temperature annealing of 5A02 material at approximately 350℃, temperature range of the test is set between 180℃~300℃, stop heating when 10℃ is added to test temperature each time.

Fit dimension test data after thermal expansion as shown on table 1.

Table 1

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
	Fit dimension φ109				
24℃（Ambient temperature）	108.96	108.95	108.95	108.96	108.97
180℃	109.3	109.29	109.3	109.31	109.31
190℃	109.34	109.33	109.33	109.35	109.35
200℃	109.38	109.36	109.35	109.38	109.39
210℃	109.41	109.40	109.39	109.41	109.42
220℃	109.44	109.43	109.42	109.43	109.44
230℃	109.46	109.46	109.46	109.47	109.46
240℃	109.48	109.48	109.49	109.5	109.47
250℃	109.51	109.50	109.51	109.51	109.52
260℃	109.54	109.52	109.53	109.54	109.55
270℃	109.56	109.56	109.55	109.56	109.58

280℃	109.59	109.58	109.60	109.58	109.61
290℃	109.62	109.61	109.62	109.60	109.63
300℃	109.65	109.65	109.64	109.66	109.67

Table 1 (Extended)

	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
	Fit dimension ϕ109				
24℃（Ambient temperature）	108.93	108.93	108.93	108.93	108.93
180℃	109.25	109.29	109.28	109.27	109.25
190℃	109.28	109.31	109.30	109.30	109.29
200℃	109.3	109.32	109.32	109.33	109.32
210℃	109.35	109.36	109.36	109.37	109.36
220℃	109.39	109.39	109.39	109.40	109.40
230℃	109.41	109.42	109.42	109.44	109.45
240℃	109.42	109.44	109.45	109.48	109.50
250℃	109.48	109.50	109.48	109.51	109.50
260℃	109.52	109.52	109.52	109.53	109.53
270℃	109.53	109.56	109.56	109.58	109.57
280℃	109.57	109.58	109.59	109.58	109.59
290℃	109.60	109.61	109.61	109.62	109.62
300℃	109.61	109.63	109.62	109.64	109.64

Relativity curve of expansion rate and temperature is drawn by processing test data and acquire fit dimension expansion under different temperature (as show on figure 2).

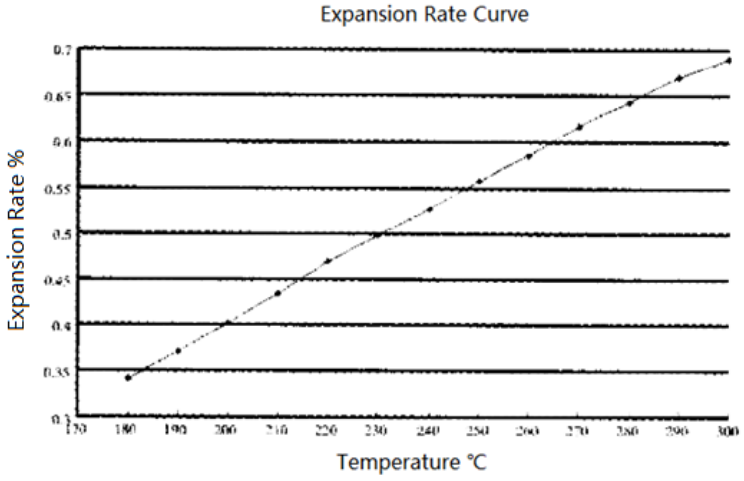

Figure 2

Test data is processed and analyzed applying approximate arithmetic, see chart of column difference quotients[5] (nominal with polynomial larger than quadric):

0.34	180		
0.53	240	322.6	
0.69	300	368.1	130.4

Polynomial of Newton interpolation between temperature and fit dimension is：

T（x）=180 + 322.6 (x - 0.34) + 130.4 (x-0.34) (x-0.53)

≈ 93.4+209.4x + 130.4x ²　　（1）

Substitute expansion rate of test data at different test temperature into the polynomial, maximum deviation between virtual heating temperature and computation of the polynomial is 1.3℃, contrast curve as shown on figure 3.

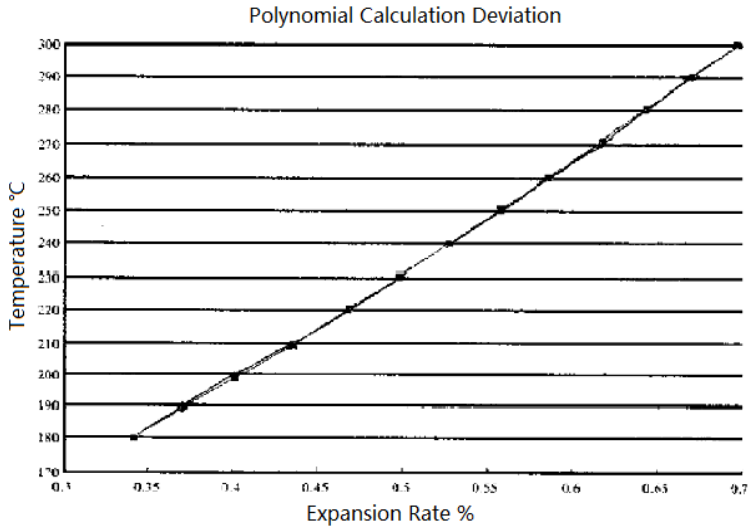

Figure 3

Apply shrinkage fit Corona Ring of another specification to verify and examine computation deviation for the acquired polynomial. Select 4 Corona Rings as test object to conduct fit dimension test after thermal expansion, test data as shown on table 2.

Table 2

	Sample 1	Sample 2	Sample 3	Sample 4
	Fit dimension φ 130			
24℃（Ambient temperature）	130.00	129.96	129.95	130.00
180℃	130.52	130.46	130.46	130.52
190℃	130.55	130.50	130.50	130.55
200℃	130.57	130.53	130.53	130.58
210℃	130.60	130.56	130.57	130.61
220℃	130.63	130.59	130.60	130.63
230℃	130.66	130.63	130.63	130.66
240℃	130.69	130.67	130.66	130.69
250℃	130.72	130.69	130.69	130.73
260℃	130.76	130.72	130.73	130.77
270℃	130.80	130.75	130.75	130.81
280℃	130.82	130.79	130.78	130.82
290℃	130.84	130.81	130.82	130.83
300℃	130.86	130.84	130.85	130.84

Table 2 (Extended)

	Sample 1	Sample 2	Sample 3	Sample 4
	Fit dimension φ 109			
24℃（Ambient temperature）	129.98	129.96	129.97	129.96
180℃	130.45	130.46	130.46	130.46

190℃	130.50	130.51	130.50	130.50
200℃	130.54	130.55	130.54	130.53
210℃	130.58	130.58	130.58	130.56
220℃	130.61	130.60	130.61	130.59
230℃	130.64	130.63	130.65	130.63
240℃	130.67	130.66	130.68	130.67
250℃	130.71	130.69	130.70	130.70
260℃	130.74	130.72	130.72	130.72
270℃	130.76	130.74	130.76	130.75
280℃	130.78	130.77	130.79	130.80
290℃	130.81	130.81	130.81	130.81
300℃	130.84	130.84	130.85	130.83

Process data in table 2 to obtain expansion rate and substitute into formula (1), calculate heating temperature obtained from polynomial, contrast the result to practical temperature, the curve is as shown on figure 3.

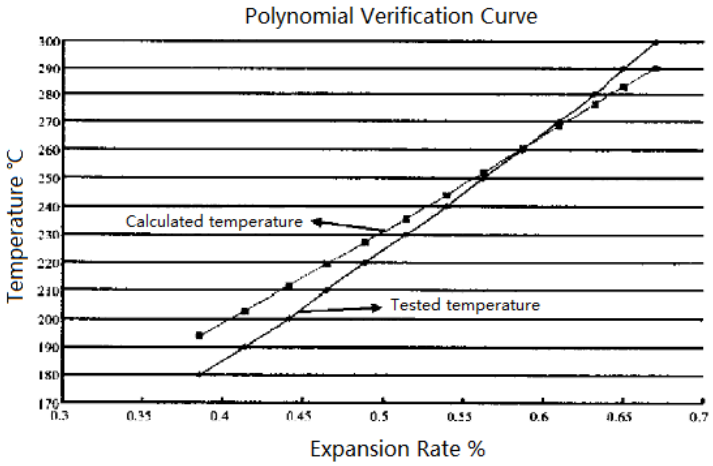

Figure 3

It can be seen after verification that polynomial gained by data fitting is capable of precise calculation of heating temperature, maximum deviation is under 8%.

Fit dimension of Corona Ring φ 109 and conductor fit dimension φ 109 applies interference fit, maximum interference is 0.308mm, required fit interval for assembly is 0.1mm, in consideration of 100% allowance, Corona Ring expansion magnitude before assembly is 0.508mm, calculation of expansion temperature should apply polynomial (1):

In the formula, value of x is (0.308+0.1×2)/108.946 ≈ 0.466%, T(x) ≈ 219.4℃. In consideration of deviation of polynomial calculation, heating temperature range from 220~240℃.

3. Conclusion

On basis of test data of Corona Ring thermal expansion, this article analyzed relativity between fit dimension expansion rate of shrinkage fit Corona Ring and heating temperature, applied approximate arithmetic to obtain relativity formula between fit dimension expansion rate of shrinkage fit shielding and heating temperature, this formula is verified applicable in calculation between fit dimension expansion rate and heating temperature. Proper thermal expansion temperature can be calculated with this formula based on fit interval required by shrinkage Corona Ring assembly. Through assembly verification, heating temperature of Corona Ring is set within

range of 220℃~240℃, process of assembly is proved to be successful, assembly acceptability is greatly improved.